METHOD OF INSPECTING THREADED FASTENERS AND A SYSTEM THEREFOR

FIELD OF THE INVENTION

The present invention relates to automated inspection systems and methods of inspection. In particular, the present invention provides a threaded fastener inspection system, and related inspection methods. Furthermore, the present invention provides systems and methods for identifying damaged threaded fasteners prior to their industrial use.

BACKGROUND

Threaded fasteners are used for many applications and must be transported during manufacture and use. During transit and processing, threaded fasteners may become damaged. For example, within a large batch of threaded fasteners, a small number of threaded fasteners may suffer thread damage as they come into contact with other fasteners or with handling equipment. The use of damaged threaded fasteners can result in a defective and potentially unsafe product.

Damaged threaded fasteners are particularly costly for automobile manufacturers. Assembly of automobile engines relies upon threaded fasteners to seal critical engine components. The use of damaged threaded fasteners can result in an improperly sealed engine that is prone to fluid leaks. Automobile manufacturers and suppliers implement post production inspection equipment to locate defective parts such as threaded fasteners. However, post production removal of fasteners is expensive as the engine may need to be disassembled and reassembled. As such, it is desirable to locate defective fasteners prior to assembly.

One inspection technique currently used is a manual inspection of each threaded fastener prior to its use within part assembly. This technique suffers from many problems. Notably, this technique is very expensive, slow, and suffers from human error.

A second inspection technique currently used involves the use of a camera to photograph the threads of a threaded fastener. One problem with this approach is that the camera is unable to capture the entire thread of the threaded fastener. Only a

single profile is generally observed. If a thread defect is oriented away from the photographic range of the camera, it will remain undetected.

Accordingly, what is needed in the art are systems and methods for identifying damaged threaded fasteners prior to incorporation into an assembled product.

SUMMARY

The present invention relates to automated inspection systems and methods of inspection. In particular, the present invention provides a threaded fastener inspection system, and related inspection methods. Furthermore, the present invention provides systems and methods for identifying damaged threaded fasteners prior to their industrial use.

Accordingly, the present invention provides a threaded fastener inspection system. In preferred embodiments the threaded fastener inspection system comprises a conveyor, at least one imaging device, and a computer processor. In some embodiments, the imaging device images threaded fasteners at a plurality of views during rotation of a threaded fastener along the conveyor. In further embodiments, the computer processor interfaces with the imaging device. In further embodiments, the computer processor is programmed to analyze the major and minor diameters of the threaded fastener at said plurality of views and compare said major and minor diameters to predetermined values to detect threaded fastener damage.

In further preferred embodiments, the conveyor comprises a rail and a belt. In some embodiments, a portion of said belt is aligned along the length of the rail so that threaded fasteners are secured between the belt and the rail and so that movement of the belt results in the rotation of a threaded fastener along the rail. In preferred embodiments, the rail is a spring loaded rail.

In other preferred embodiments, the imaging device captures an image of threaded fasteners for each 30 degree rotation a threaded fastener makes as it travels within the range of view of the imaging device. In preferred embodiments, the imaging device is stationary.

In some preferred embodiments, the conveyor further comprises a distal end and a sorter, wherein the sorter is positioned at the distal end of the conveyor and wherein the sorter is activated when the computer processor identifies a defective

threaded fastener so that damaged threaded fasteners are sorted from undamaged threaded fasteners. In further embodiments, the sorter is a trapdoor. In even further embodiments, the threaded fasteners identified as damaged are discarded into the sorter.

In further preferred embodiments, an illumination device is oriented opposite of the imaging device.

In some embodiments, the present invention provides a threaded fastener head damage inspection system in combination with the thread inspection system, wherein the head damage inspection system comprises a rotating tray having a plurality of openings therein for receiving threaded fasteners and at least one head damage imaging device, wherein the at least one head damage imaging device images the threaded fasteners, and a head damage computer processor interfaced with the head damage imaging device, wherein the head damage computer processor is programmed to analyze the threaded fastener heads of the threaded fasteners and compare the threaded fastener heads to default limits to detect threaded fastener head damage.

In some embodiments, the threaded fasteners are securable within the plurality of openings so that the threaded fastener head is exposed. In further embodiments, the conveyor is positioned to accept threaded fasteners exiting from the threaded fastener head damage inspection system. In even further embodiments, the threaded fastener head damage is selected from the group consisting of cracks, splits, and improper sealing.

The present invention further provides a method of identifying damaged threaded fasteners, comprising providing threaded fasteners, rotating said threaded fasteners, imaging the threaded fasteners at a plurality of views during the rotation, determining major and minor diameters of the threaded fasteners at the plurality of views, comparing the major and minor diameters to predetermined values to determine if the threaded fasteners are damaged, and sorting damaged threaded fasteners from undamaged threaded fasteners. In further embodiments, the comparing is performed by a computer processor.

In even further embodiments, the threaded fasteners are rotated on a conveyor. In still further embodiments, the imaging is performed by a digital camera.

In some embodiments, the at least one imaging device captures an image of the threaded fasteners for each 30 degrees of rotation a threaded fastener undergoes as said threaded fastener travels within the range of view of said at least one imaging device. In further embodiments, six views are captured.

Other features and advantages of the invention will become apparent to those skilled in the art upon review of the following detailed description, claims and drawings in which like numerals are used to designate like features.

FIGURE DESCRIPTION

FIG. 1A illustrates an undamaged threaded fastener and FIG. 1B illustrates a damaged threaded fastener.

FIG. 2 illustrates a threaded fastener thread damage inspection system.

FIG. 3 illustrates a threaded fastener in the threaded fastener thread damage inspection system of FIG. 2.

FIG. 4 illustrates the inspection area of the threaded fastener thread damage inspection system.

FIG. 5A-F illustrate the range of view of an imaging device within the threaded fastener thread damage inspection system.

FIG. 6 illustrates a threaded fastener head damage inspection system.

FIG. 7 schematically illustrates a threaded fastener inspection system.

Before the embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein are for the purpose of description and should not be regarded as limiting. The use of "including" and "comprising" and variations thereof is meant to encompass the items listed thereafter and equivalents thereof as well as additional items and equivalents thereof.

DETAILED DESCRIPTION

The present invention provides inspection systems and methods. The illustrated and preferred embodiments discuss these techniques in the context of threaded fastener inspection systems and methods. However, it should be appreciated that the invention is applicable for use in other inspection applications.

The threaded fastener inspection systems and methods of the present invention have numerous advantages over previous prior art devices including, but not limited to, a faster and more precise approach toward assessing threaded fastener damage. FIGS. 1-7 show various preferred embodiments of the threaded fastener inspection systems and methods of the present invention. The present invention is not limited to these particular embodiments.

The present invention provides systems and methods for detecting thread damage within threaded fasteners. Threaded fasteners refer to hardware agents comprising a threaded face and a head. Examples include, but are not limited to, threaded workpieces, nuts, screws, set screws, grub screws, threaded bolts, and the like.

FIG. 1 generally illustrates an undamaged threaded fastener **10** and a damaged threaded fastener **15**. A threaded fastener thread face generally comprises a continuous helical ridge **20** formed on the inside (nut) or outside (screw) of a cylinder **25**. The apex of the ridge **20** is called the crest **30**. Between each crest is a space, called the root **35**. Threads are set at an angle to the axis **40** of the bolt or nut. This slope is called the helix angle **45**. The helix angle **45** must be sloped, either to the right (for right-hand threaded screws) or the left (for left-hand threaded screws). The threads on a threaded fastener further comprise a major diameter **50** and a minor diameter **55**. The major diameter **50** refers to the outside diameter of the thread face and is measured from the outer edge of the crest **30**. The minor diameter **55** refers to the inside diameter of the thread face and is measured from the outer edge of the root **35**. An undamaged threaded fastener **10** has predetermined or default undamaged major diameter **50** and minor diameter **55** distances. A threaded fastener with damaged threads will have major diameter **50** and minor diameter **55** distances inconsistent with the default undamaged major diameter **50** and minor diameter **55** distances. Referring to FIG. 1, the damaged threaded fastener **55** has a blemish **60**

(*e.g.*, a nick or a strip in the thread face) within the thread face. The blemish **60** results in a major diameter **50** distance inconsistent with the undamaged threaded fastener **10** major diameter **50** distance.

The present invention provides systems and methods wherein threaded fasteners are rotatably transported during inspection. Rotatable transport of a threaded fastener refers to rotation of the threaded face along a surface (*e.g.*, rail) resulting in the movement of the threaded fastener along the surface. The thread face may be rotated clockwise or counterclockwise depending on the desired direction of transport. Rotatable transport of a threaded fastener is not limited to a particular speed of transport. In addition, a threaded fastener may be rotatably transported such that the thread head is positioned above, below, or along the direction of transport.

FIG. 2 illustrates an inspection system **100** of the present invention. In preferred embodiments, the inspection system **100** comprises a conveyor **105**, an inspection area **110**, a computer processor **115**, and a sorter **120**.

The conveyor **105** of the present invention rotatably transports threaded fasteners. A conveyor **105** may be driven automatically or manually. In preferred embodiments, the conveyor **105** is driven by an electric motor **145**. In some embodiments, the conveyor **105** is positioned at an incline from the conveyor proximal end **125** to the conveyor distal end **130**. The conveyor **105** may operate at any desired speed of transport. The conveyor **105** is not limited to a particular length. In preferred embodiments, the conveyor **105** comprises a rail **135** and a belt **140**.

In preferred embodiments, the rail **135** comprises any type of material (*e.g.*, steel, metal, plastic, wood) or mixture of such materials. The rail **135** is not limited to a particular length or width. In preferred embodiments, the width of the rail **135** is small in comparison to the length of the threaded fastener so that only a small portion of the face of the threaded fastener is obscured by the rail **135**. In preferred embodiments, the rail **135** is a spring loaded rail.

In preferred embodiments, the rail **135** is a spring loaded rail **175**. In some embodiments, the spring loaded rail **175** comprises at least one spring **180** and **185**. In some embodiments, the spring **180** is positioned around a cylinder **200**. The cylinder **200** can comprise any type of material (*e.g.*, metal, plastic) or any mixture of such materials. The cylinder **200** is not limited by a particular length or width. The

springs **180** and **185** may be adjusted to create a desired tension. In preferred embodiments, the spring loaded rail **175** contains two springs **180** and **185**. In further embodiments, the two springs **180** and **185** are positioned at the proximal end **190** and the distal end **195** of the spring loaded rail **175**. In even further embodiments, the two springs **180** and **185** are positioned across from rollers **150** positioned at the proximal and distal ends of the belt **140**.

The belt **140** can preferably comprise any type of material (*e.g.*, rubber, metal, leather, plastic) or mixture of such materials. The belt **140** may be driven automatically or manually. In preferred embodiments, the belt **140** is driven by a motor **145**. The belt **140** is not limited to a particular length or width. In preferred embodiments, the belt **140** is approximately ¼ inch thick. In some embodiments, a fixed shape is maintained in the belt **140** through a plurality of rollers **150**. In preferred embodiments, rollers **150** are positioned at the belt proximal end **155** and the belt distal end **160** of the belt **140**.

In preferred embodiments, threaded fasteners **136** are rotatably transported in between the rail **135** and the belt **140**. The belt **140** is positioned along the rail **135**. A threaded fastener **136** enters the conveyor **105** at the proximal end **165** of the rail **135**. In some embodiments, the proximal end **165** of the rail **135** is rounded **170** to facilitate the entrance of threaded fastener **136** in between the rail **135** and the belt **140**.

FIG. 3 illustrates a threaded fastener in between the rail **135** and the belt **140**. The upper end of the threaded fastener thread face is positioned in between the rail **135** and the belt **140**. The head of the threaded fastener is positioned above the rail **135** and the belt **140**. The movement of the belt **140** results in the threaded fastener transporting along the rail **135**. Alternatively, the head of the threaded fastener can ride on a pair of spaced apart rails with the belt **140** being located beneath one of the rails.

Returning to FIG. 2, the inspection area **110** comprises an imaging device **205** and an illumination device **210**. The imaging device **205** (*e.g.,* digital camera) may further be positioned anywhere along the length of the rail **135**. The imaging device **205** may be held in a stationary position or may be mobile. In preferred embodiments, the imaging device **205** is stationary. The present invention is not

limited to any particular type of imaging device **205**. Furthermore, the imaging device **205** may be adjusted to accommodate imaging of threaded fasteners of various sizes and shapes.

The inspection area **110** further comprises an illumination device **215** (*e.g.*, light bulb). The illumination device **215** is not limited to any particular strength (*e.g.*, wattage). In some embodiments, the illumination device **215** is positioned beneath the belt **140** so that a threaded fastener traveling along the conveyor **105** is back-lit. The illumination device **215** is further positioned directly across from the imaging device **205**.

FIG. 4 illustrates a threaded fastener within an inspection area **110**. An imaging device **205** (*e.g.*, digital camera) is positioned below the rail **135**. In preferred embodiments, the imaging device **205** is positioned so that the upper end of the imaging device lens **210** is positioned in line with the lowest point of the rail **135**. As discussed above, a threaded fastener positioned between the rail **135** and belt **140** will have the majority of its threaded face exposed beneath the rail **135** and belt **140**. The imaging device lens **210** is further positioned so as to be within view of the exposed threaded face, preferably the entire exposed threaded face, of a threaded fastener positioned between the rail **135** and belt **140**.

The present invention is configured to image the thread face of a threaded fastener traveling along the rail **135**. In preferred embodiments, a rotating threaded fastener passing within the range of view of the imaging device **205** will expose at least half (*e.g.*, 180 degrees) of its face to the imaging device lens **210**. It will be recognized that the speed of the motor **145** can be varied to vary the speed of the belt **140** and thus the speed of rotation of the threaded fastener. The imaging device **205** is configured to capture a plurality of images of the thread face of a threaded fastener rotating along the rail **135**. In preferred embodiments, the imaging device **205** is programmed according to this speed of rotation so that it can capture an image of the threaded fastener for each 30 degree rotation the threaded makes as it travels within the range of view of the imaging device lens **210**. As illustrated in FIG. 5, in preferred embodiments the imaging device **205** captures images of the entire (*e.g.*, 360 degree) face of a rotating object if six images are compiled of the rotating object at six successive 30 degree intervals. In addition, six images of a rotating object taken

at six successive 30 degree increments ensures that overlapping profiles of the face of the rotating object are captured. Other angles can be used, so long as the increments provide an overlapping profile of the face of the rotating object being captured.

In preferred embodiments, the imaging device **205** is configured to capture six images of the thread face of a threaded fastener rotating along the rail **135**. In further preferred embodiments, the imaging device **205** is configured to capture six images of the thread face of a threaded fastener at six successive 30 degree intervals as the threaded fastener rotates along the rail **135**.

In preferred embodiments, the imaging device **205** provides images of the thread face of a threaded fastener to the computer processor **115**. The present invention is not limited to any type of computer processor **115**. In some embodiments, the computer processor **115** is a part of the imaging device **205**, while in other embodiments, the computer processor **115** is interfaced with imaging device **205** via a computer cable. The computer processor **115** is programmed to detect damaged threaded fastener thread faces by analyzing the images obtained from the imaging device **205** and comparing the data obtained from this analysis with a set of predetermined threaded fastener face criteria. According to one aspect of the invention, the inspection system is looking for the absence of light. If light is present during the inspection process, the system recognizes that a flaw or defect may be present in the threaded fastener. According to another aspect of the invention, default major and minor diameters for undamaged fasteners are compared to the imaged major and minor diameters. Threaded fasteners not meeting the predetermined threaded fastener face criteria are sorted via a sorter **120**. In preferred embodiments, the sorter **120** is a trapdoor.

Referring to FIG. 6, in another embodiment of the present invention, an inspection system for detecting threaded fastener head is provided. A bin **300** connects with a chute **305** (*e.g.*, conveyor belt). The chute **305** connects with a rotating tray **310** (*e.g.*, rotating turn table). The rotating tray **310** can be operated at a variety of predetermined speeds. The rotating tray **310** has a therein a plurality of rotating tray openings **315** that receive threaded fasteners from the chute **305**. In preferred embodiments, the rotating tray **310** comprises six rotating tray openings **315**. In some embodiments, the rotating tray **310** connects with both a discard device

320 and a threaded fastener inspection system (see FIG. 7). In preferred embodiments, at least one head or seal damage imaging device **325** is positioned above the rotating tray **310**. In preferred embodiments, the head or seal damage imaging device **325** interfaces with a head or seal damage computer processor **330**.

The chute **305** is configured to transfer a plurality of threaded fasteners from the bin **300** into available (*e.g.,* empty, unoccupied) rotating tray openings **315**. In preferred embodiments, the rotating tray openings **315** are configured to secure the thread face of threaded fasteners thereby leaving the heads of secured threaded fasteners exposed.

Threaded fastener heads may be damaged in numerous manners (*e.g.,* cracked heads, unsealed heads, split heads). In preferred embodiments, the head or seal damage imaging device **325** is positioned above the rotating tray **310** so as to facilitate the capturing of a plurality of images of the heads of threaded fasteners secured within rotating tray openings **315**. The head or seal damage imaging device **325** further provides such images of the heads of threaded fasteners to the head or seal damage computer processor **330**. The head or seal damage computer processor **330** is programmed with predetermined undamaged threaded fastener head criteria. In preferred embodiments, the head or seal damage computer processor **330** implements a program to compare the image of a threaded fastener head with the predetermined undamaged threaded fastener head criteria. As such, the head or seal damage computer processor **330** is programmed to analyze digital images captured by the head or seal damage imaging device **325** to detect damaged threaded fastener heads. According to another aspect of the invention, the inspection system is looking for the absence of light. If light is present during the inspection process, the system recognizes that a flaw or defect may be present in the threaded fastener head. In preferred embodiments, threaded fastener heads meeting the predetermined undamaged threaded fastener head criteria are provided to a threaded fastener inspection system (discussed above). Threaded fastener heads not meeting the predetermined criteria are provided to the discard device **320**.

FIG. 7 schematically illustrates a threaded fastener inspection system embodiment for inspecting a plurality of threaded fasteners. In particular, a threaded fastener head damage inspection system **400** interfaces with a first discard location

405 and/or a threaded fastener thread damage inspection system **410**. The threaded fastener thread damage inspection system **410** interfaces with either a second discard location **415** or an acceptance location **420**. The present invention is not limited to a particular threaded fastener inspection system configuration. Indeed, in some embodiments the present invention provides only a threaded fastener head damage inspection system **400** or only a threaded fastener thread damage inspection system **410**. In preferred embodiments, the present invention provides both a threaded fastener head damage inspection system **400** and a threaded fastener thread damage inspection system **410**.

Variations and modifications of the foregoing are within the scope of the present invention. It is understood that the invention disclosed and defined herein extends to all alternative combinations of two or more of the individual features mentioned or evident from the text and/or drawings. All of these different combinations constitute various alternative aspects of the present invention. The embodiments described herein explain the best modes known for practicing the invention and will enable others skilled in the art to utilize the invention. The claims are to be construed to include alternative embodiments to the extent permitted by the prior art.

Various features of the invention are set forth in the following claims.